Preliminary Study of the $^{19}F(p,\gamma)^{20}Ne$ at LUNA

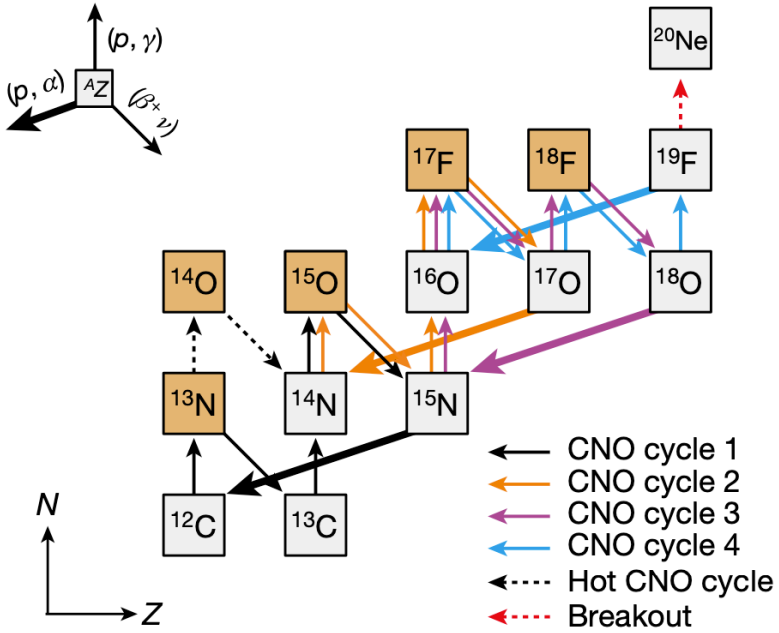
J. Skowronski

Università degli Studi di Padova, Padova, Italy
Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Padova, Italy

29/05/2025

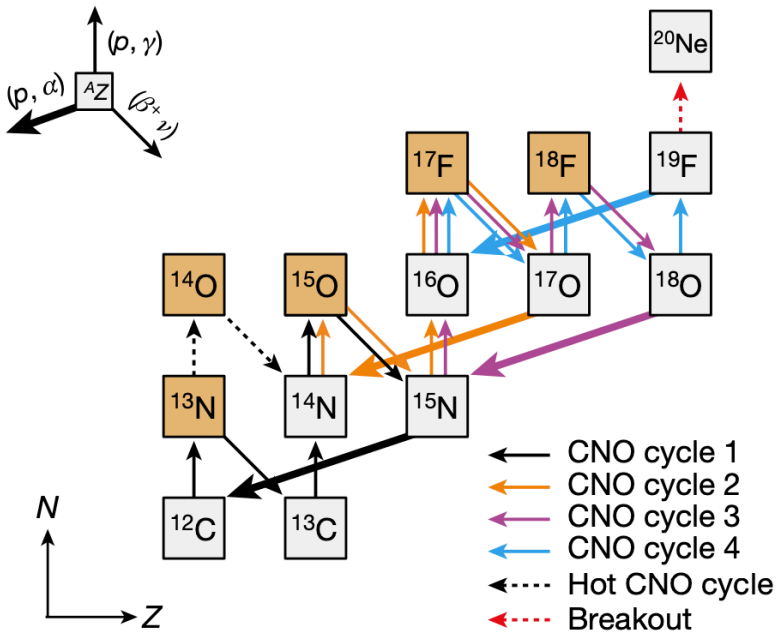
$^{19}F(p,\gamma)^{20}Ne$ Reaction: Motivation

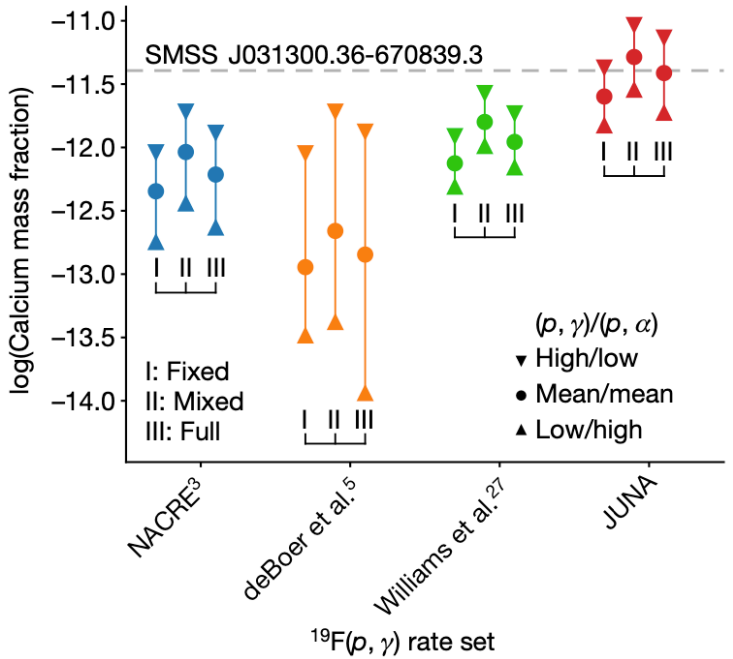
- Link between the **CNO** and **NeNa** cycles



$^{19}F(p,\gamma)^{20}Ne$ Reaction: Motivation

- Link between the **CNO** and **NeNa** cycles
- **Hot CNO** breakout may play a key role in explaining the observed **Ca abundance** in metal-poor stars

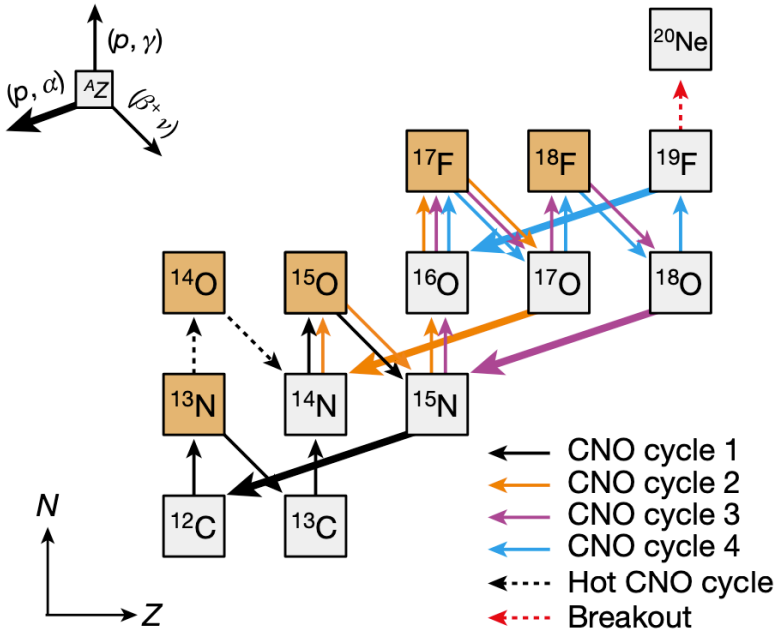


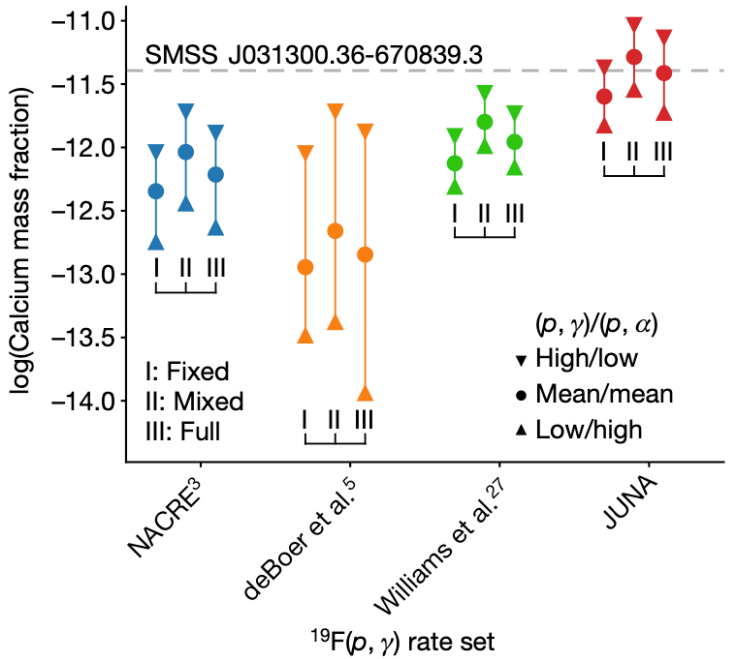


Zhang et al. Nature 610, 656 (2022)

$^{19}F(p,\gamma)^{20}Ne$ Reaction: Motivation

- Link between the **CNO** and **NeNa** cycles
- **Hot CNO** breakout may play a key role in explaining the observed **Ca abundance** in metal-poor stars
- **$^{19}F(p,\gamma)^{20}Ne$** and **$^{19}F(p,\alpha)^{16}Ne$** ratio defines the evolution of first stars

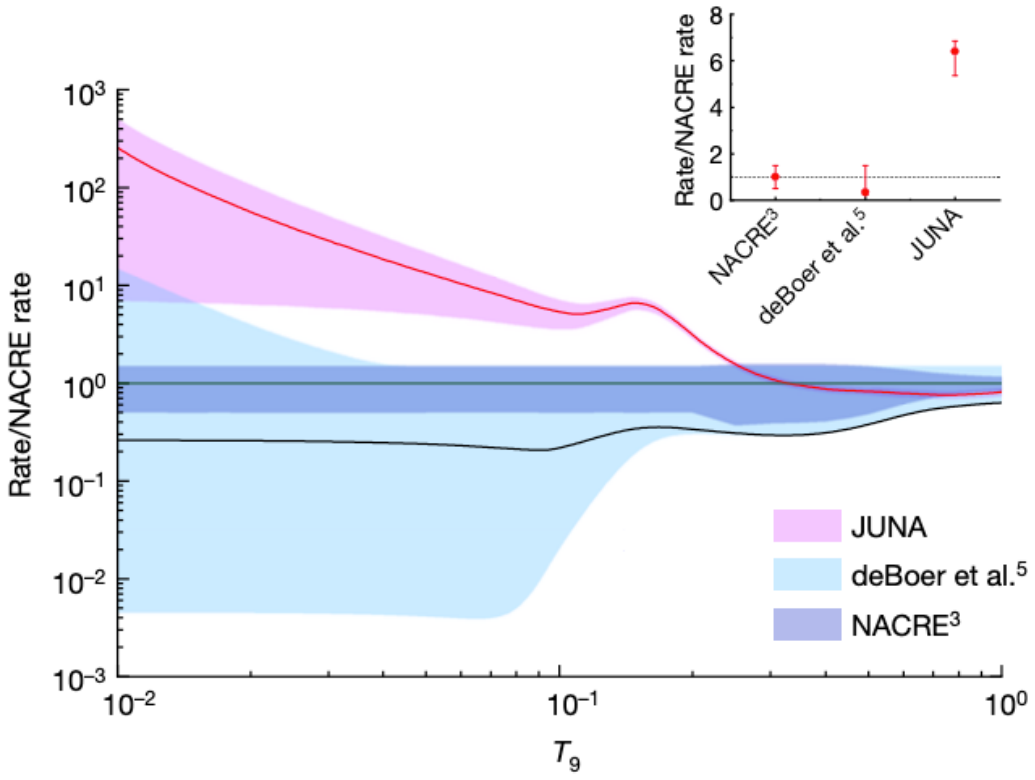




Zhang et al. Nature 610, 656 (2022)

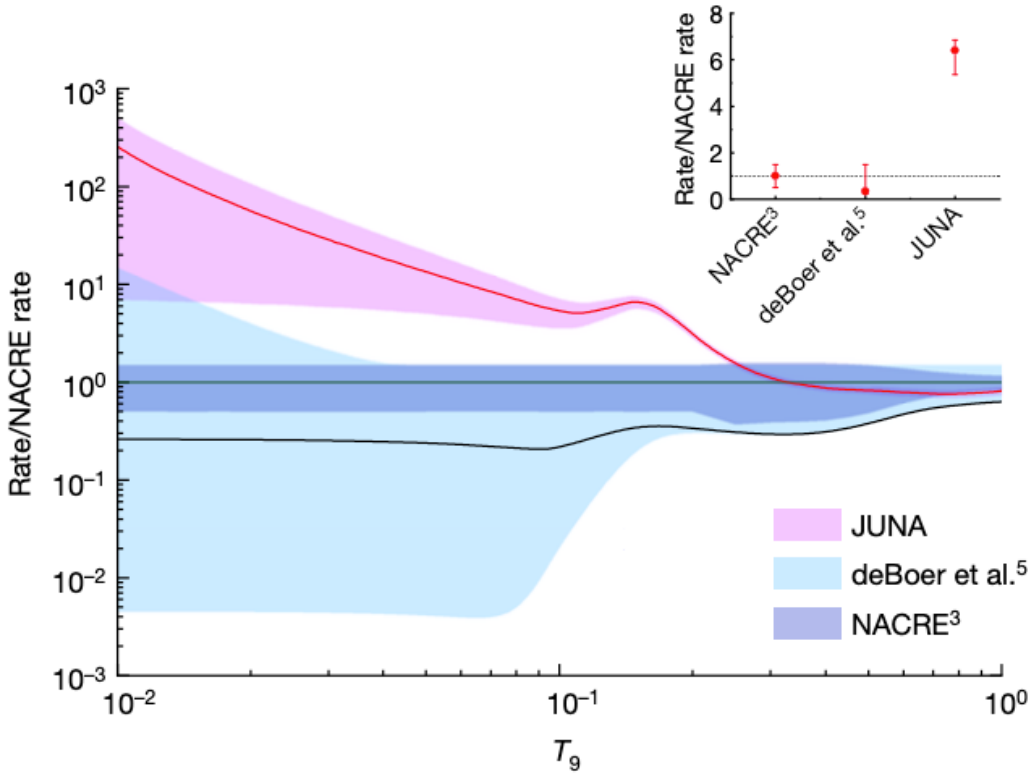
$^{19}F(p,\gamma)^{20}Ne$ Reaction: State-of-the-Art

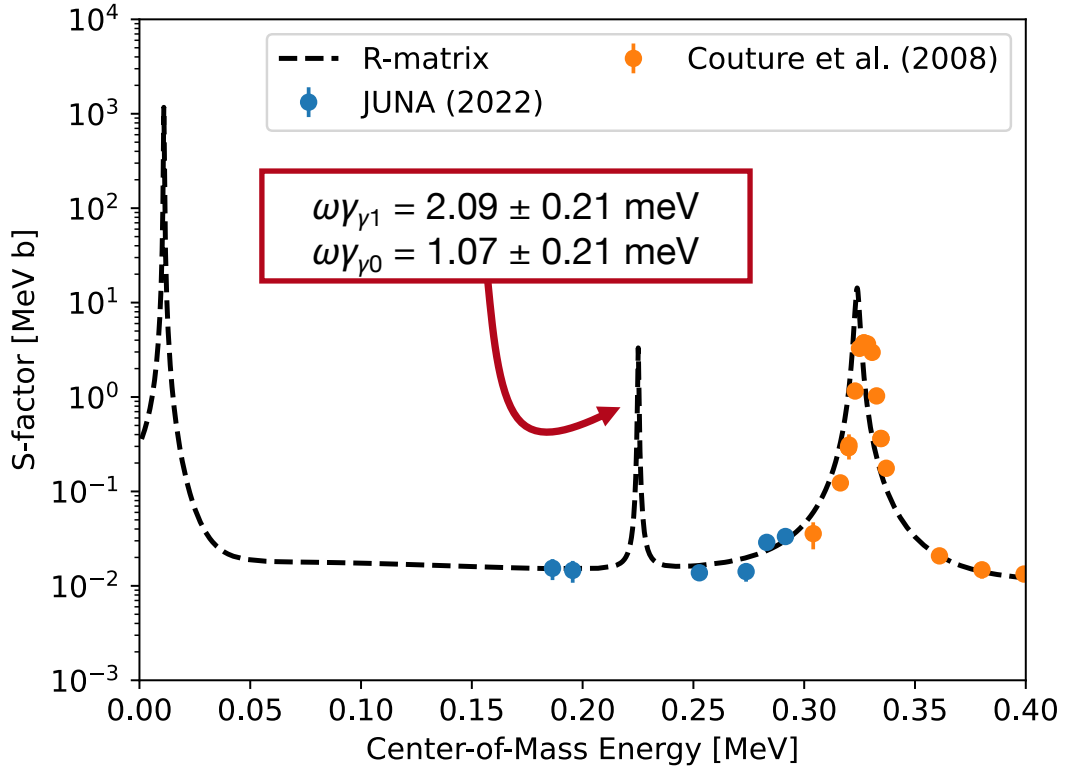
- Zheng et al. (2022) found the $\mathbf{E_{cm}}$ **= 225 keV** resonance, drastically enhancing the reaction rate (Fig. 2)



$^{19}F(p,\gamma)^{20}Ne$ Reaction: State-of-the-Art

- Zheng et al. (2022) found the **E_{cm} = 225 keV** resonance, drastically enhancing the reaction rate (Fig. 2)
- No other literature data are available **under 300 keV**

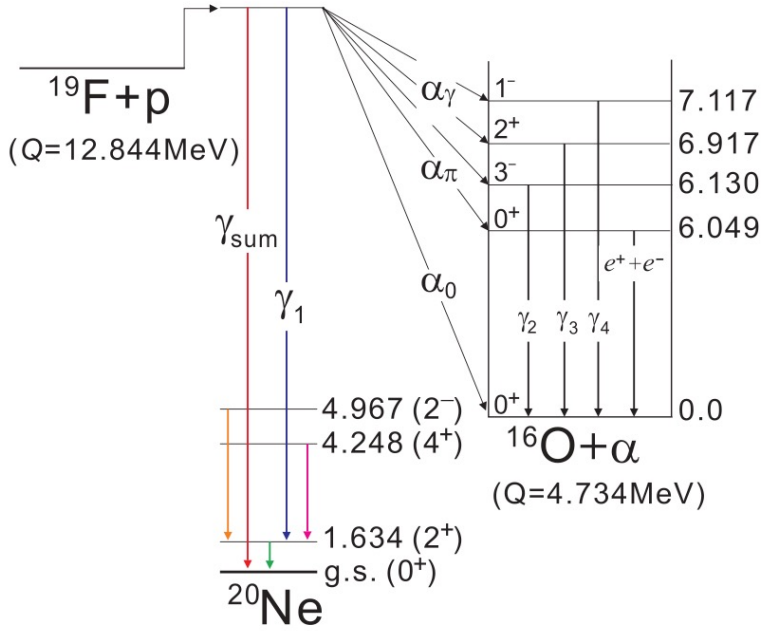


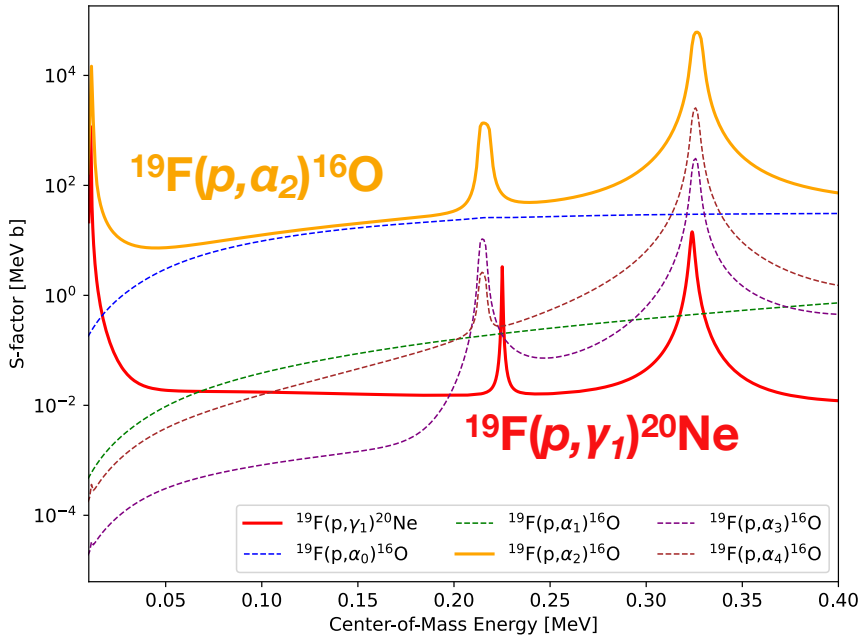


$^{19}F(p,\gamma)^{20}Ne$ and $^{19}F(p,\alpha)^{16}O$ Reactions

Main Issues

- The **$^{19}F(p,\alpha)^{16}O$** creates a huge (*pile-up*) background

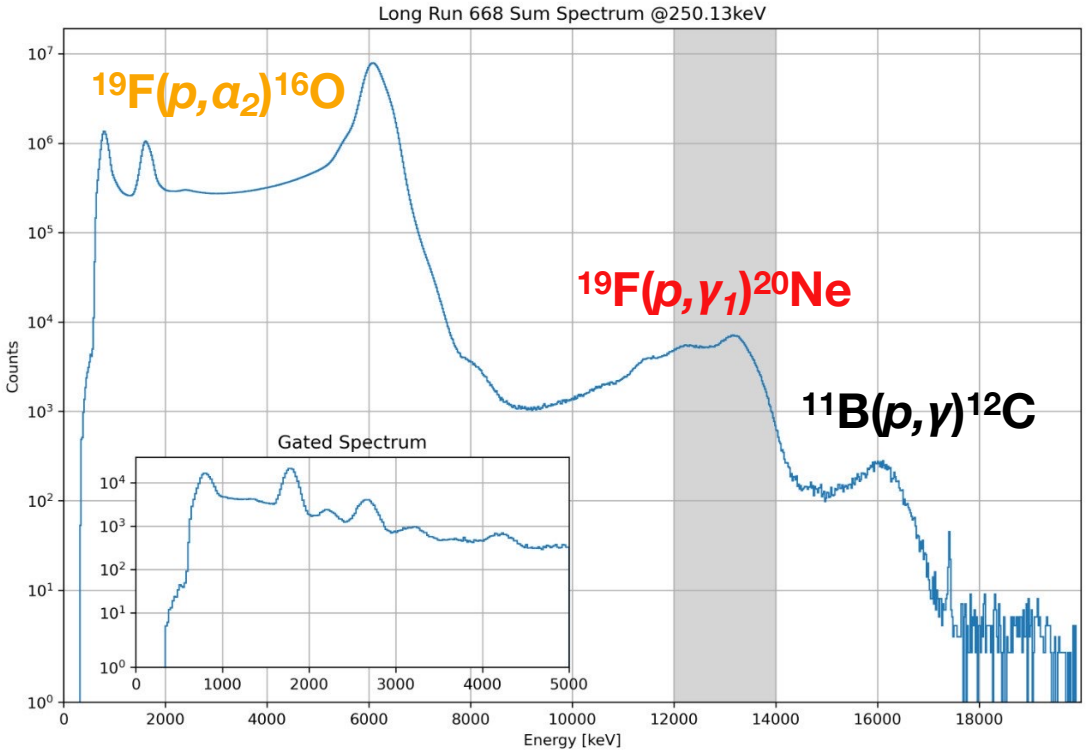


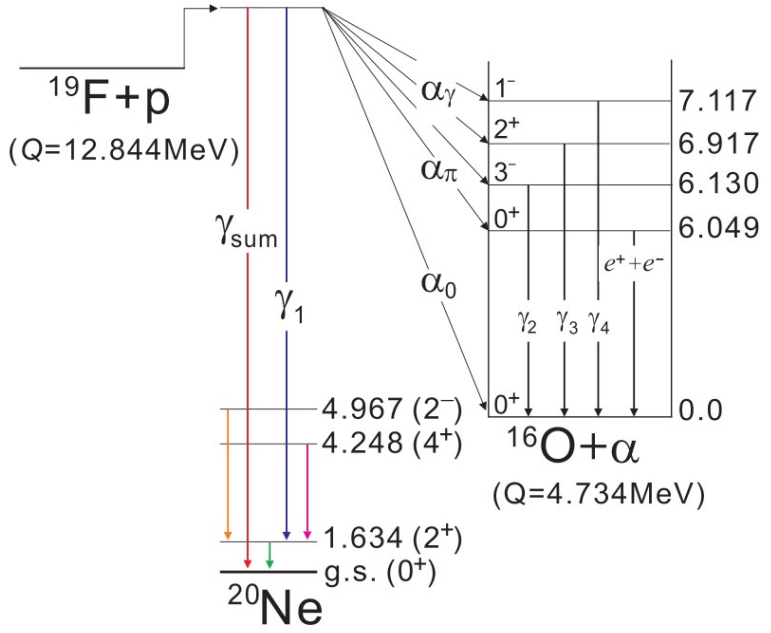


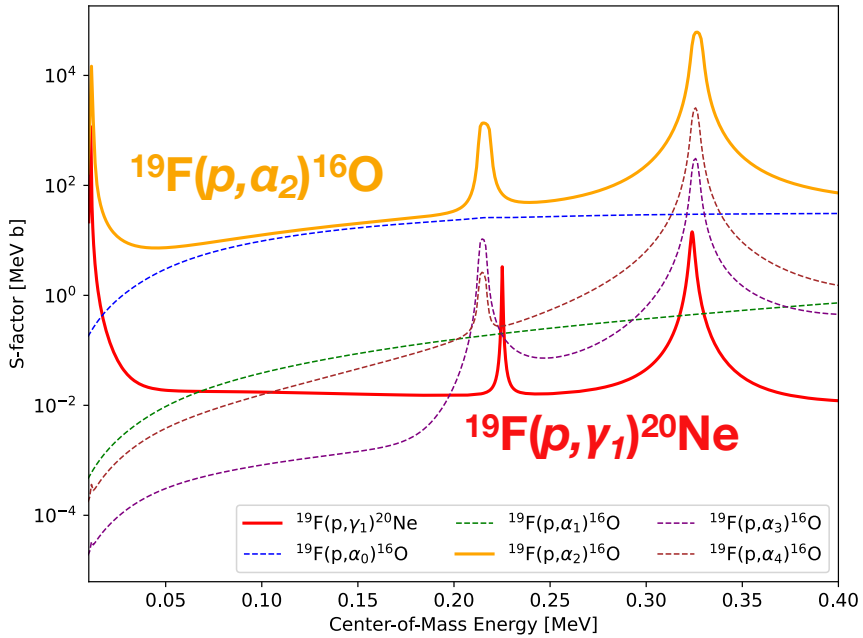
$^{19}F(p,\gamma)^{20}Ne$ and $^{19}F(p,\alpha)^{16}O$ Reactions

Main Issues

- The **$^{19}F(p,\alpha)^{16}O$** creates a huge (*pile-up*) background
- Beam-induced background from **$^{11}B(p,\gamma)^{12}C$** reaction (ppm ^{11}B contamination in target backing)

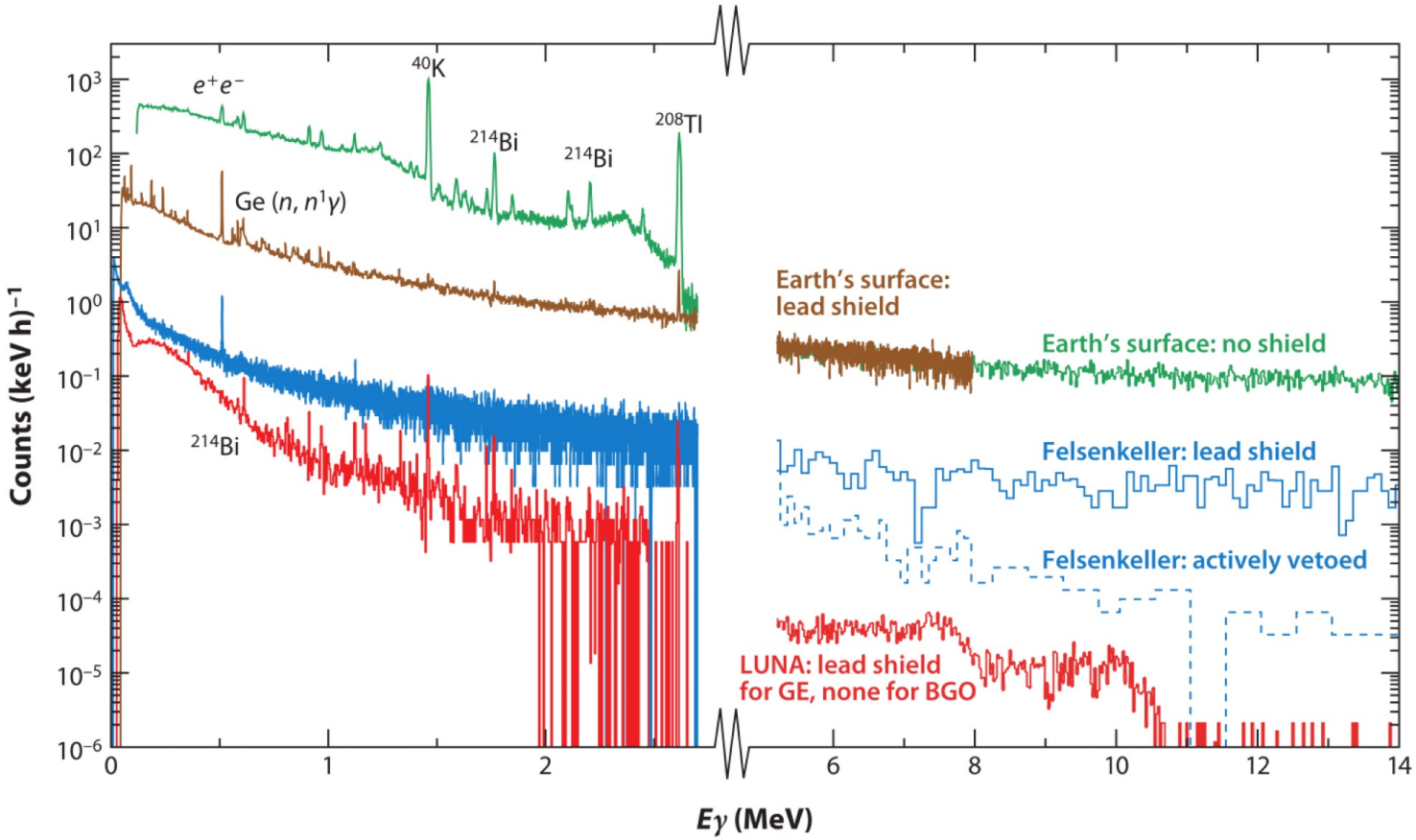






Laboratory for Underground Nuclear Astrophysics

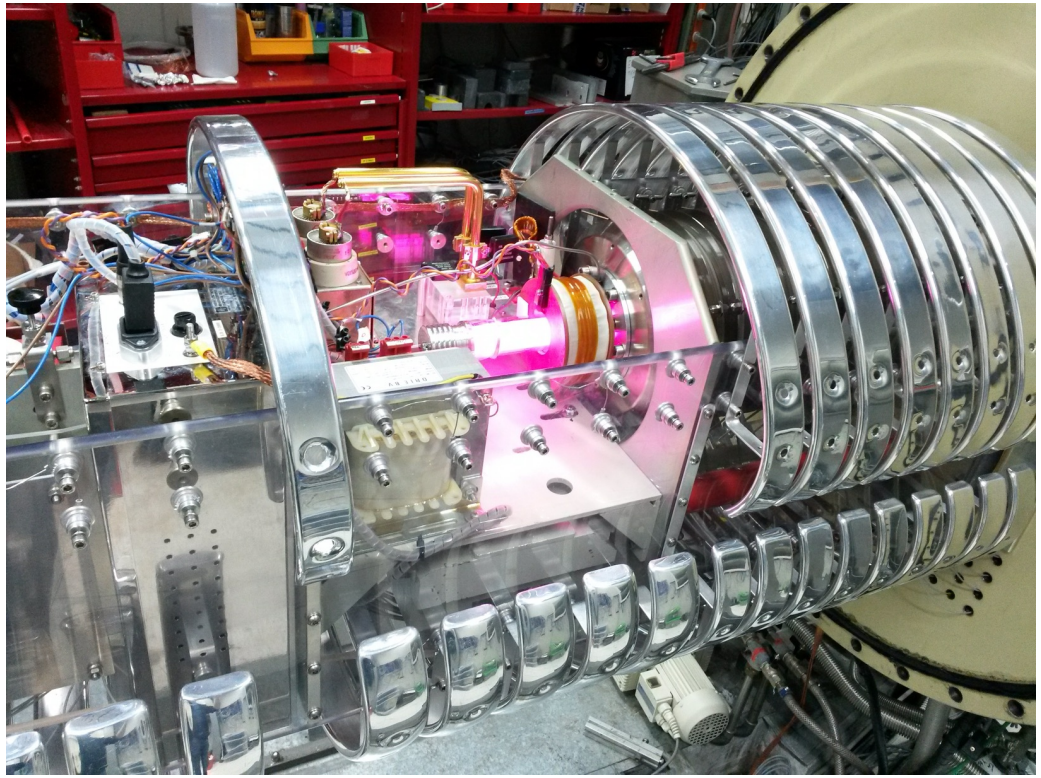
- Located **underground** at the **Laboratori Nazionali del Gran Sasso** (LNGS), Italy
- Shielded by **1400 meters** of **Gran Sasso** mountain



Accelerators at LUNA

LUNA 400kV

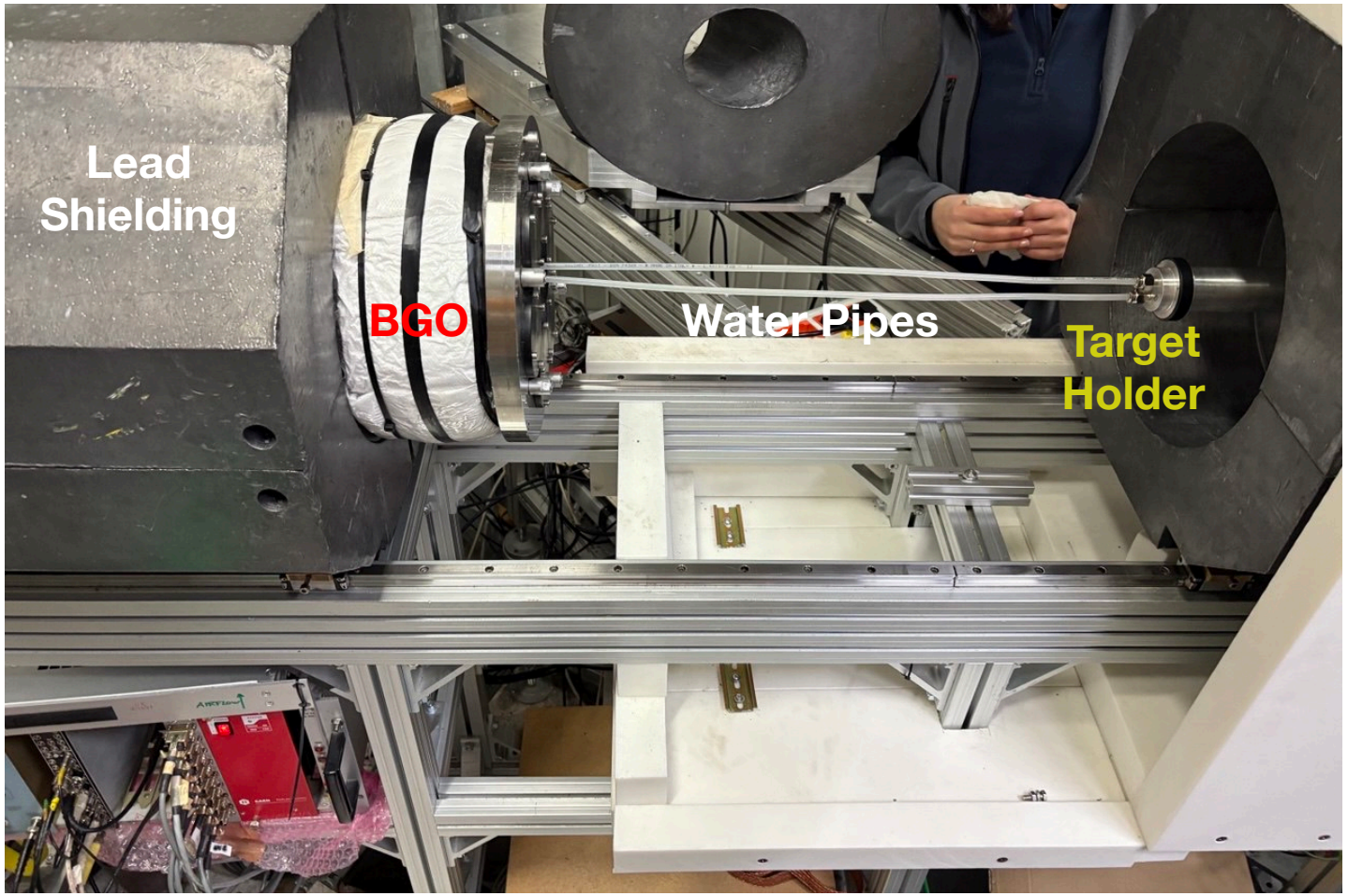
- Low energy spread (**< 100 eV**)
- Excellent stability (**~ 5 eV in an hour**)
- Intense currents (**up to 500 μA**)

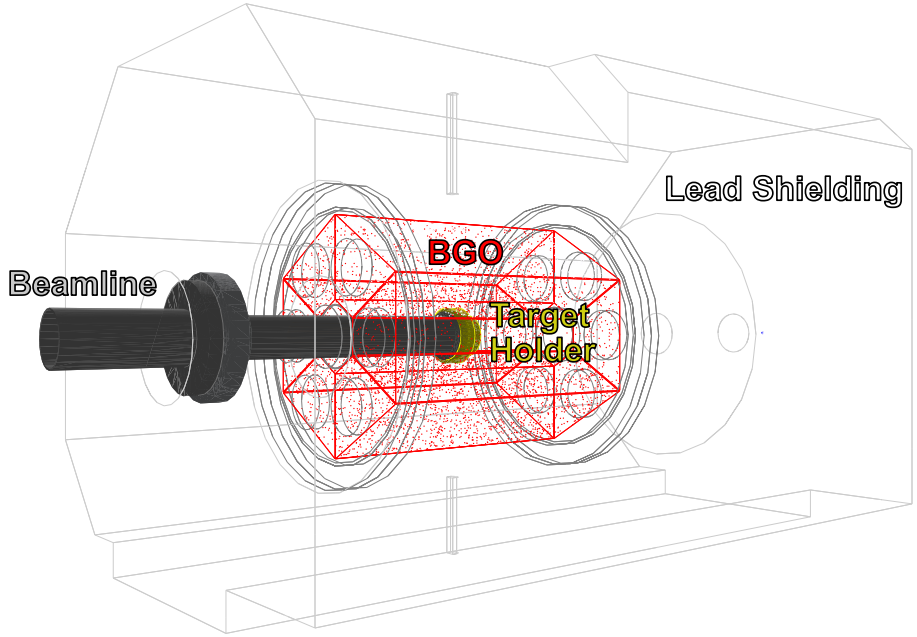


NEW – MV Accelerator

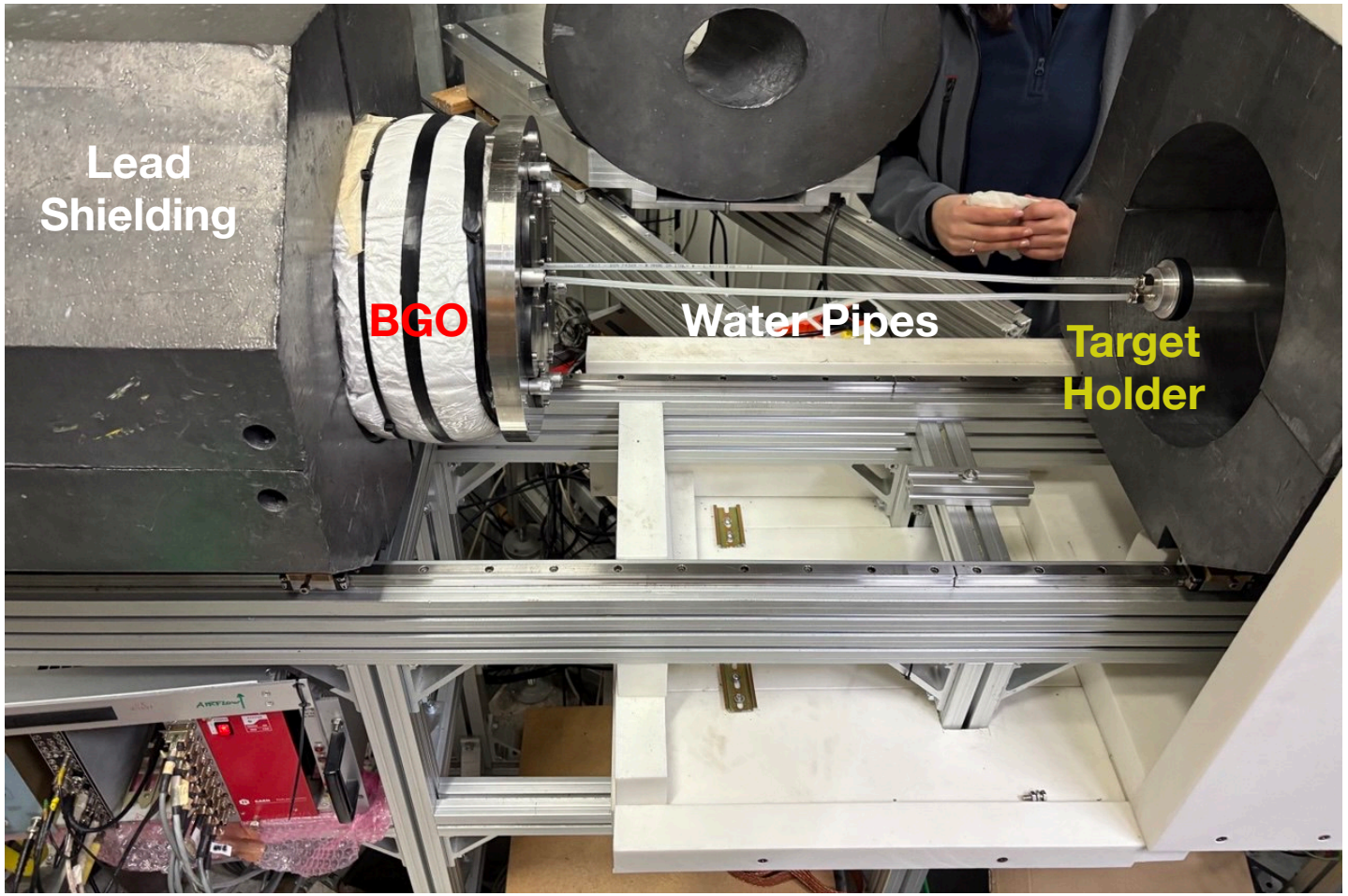
Beam characterization done, to be published soon

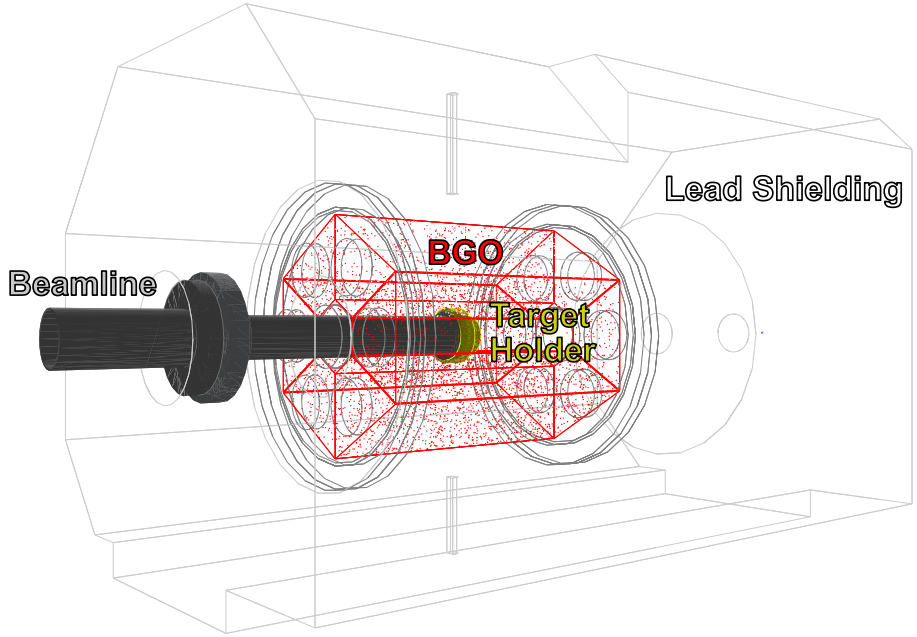
Experimental Setup



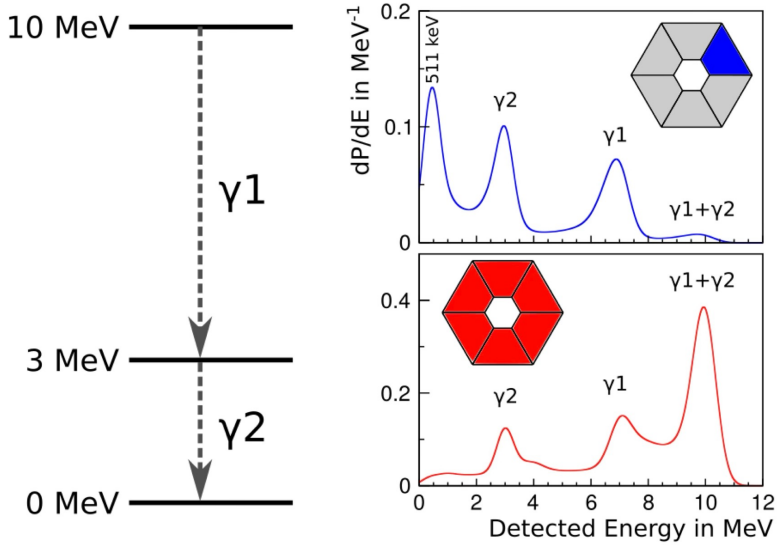


Experimental Setup





Total Absorption Spectroscopy



^{19}F Targets

Type	Composition	Thickness @ 320 keV	Backing	Coating	Reference	Stability
Evaporated	CaF_2, MgF_2, LiF	5 – 100 keV	Ta, W, Cu, C	-	[2,3,4,5]	**Degradation of 60% / Coulomb**
Implanted	-	10 – 20 keV	Ta, Fe	Cr	[1,4,5]	**Degradation of 0.05% / Coulomb**
Fluorinated	TaF_6	? keV	Ta	-	-	**?**
Sputtered	MgF_2, LiF	10 keV	Ta, Fe	Cr	[5]	**Degradation of 6% / Coulomb**

[1] Zhang et al. Nature 610 (2022)
[2] Lombardo et al. Phys. Lett. B 748 (2014)
[3] Couture et al. Phys. Rev. C **77** (2008)
[4] Zhang et al. Nucl. Inst. Meth. Phys. Res. B 438 (2019)
[5] Zhang et al. Nucl. Inst. Meth. Phys. Res. B 496 (2021)

Not available

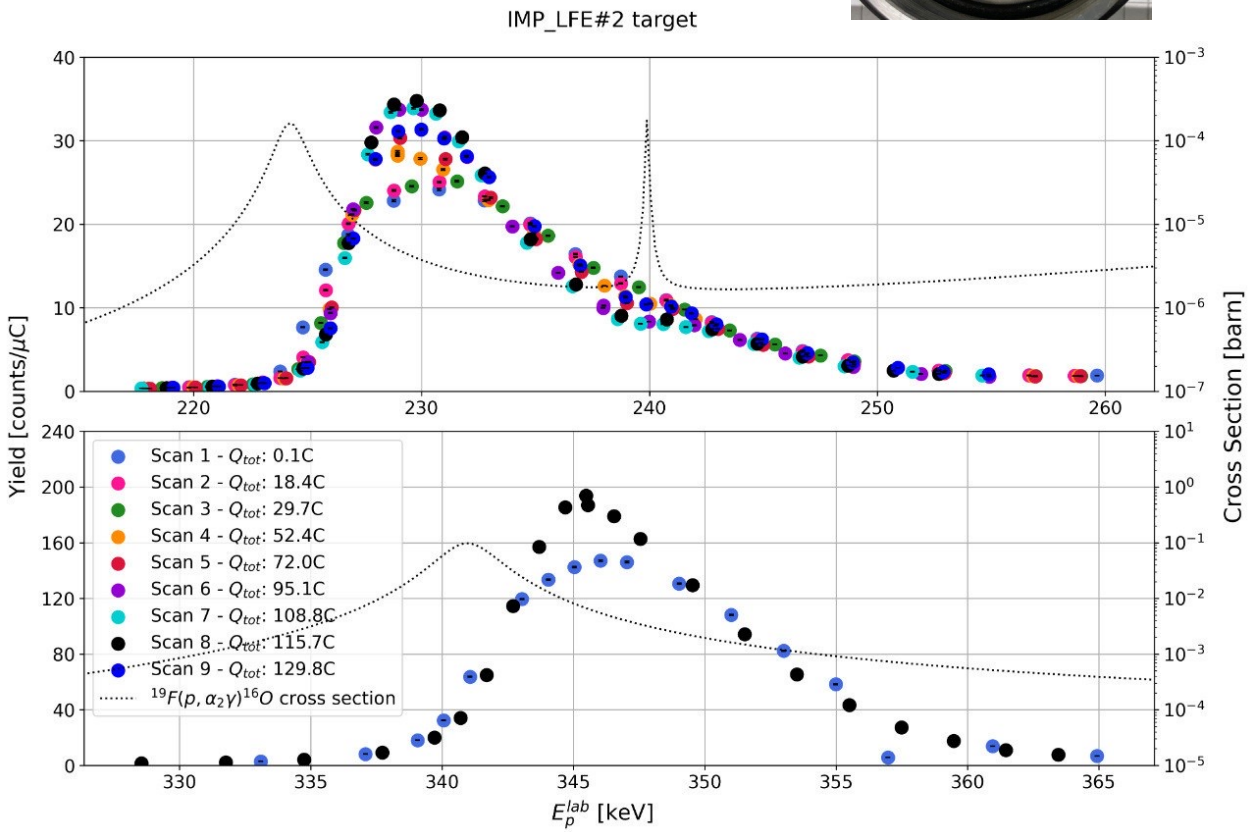
Used

New

Implanted ^{19}F Targets

Implanted ^{19}F in Fe

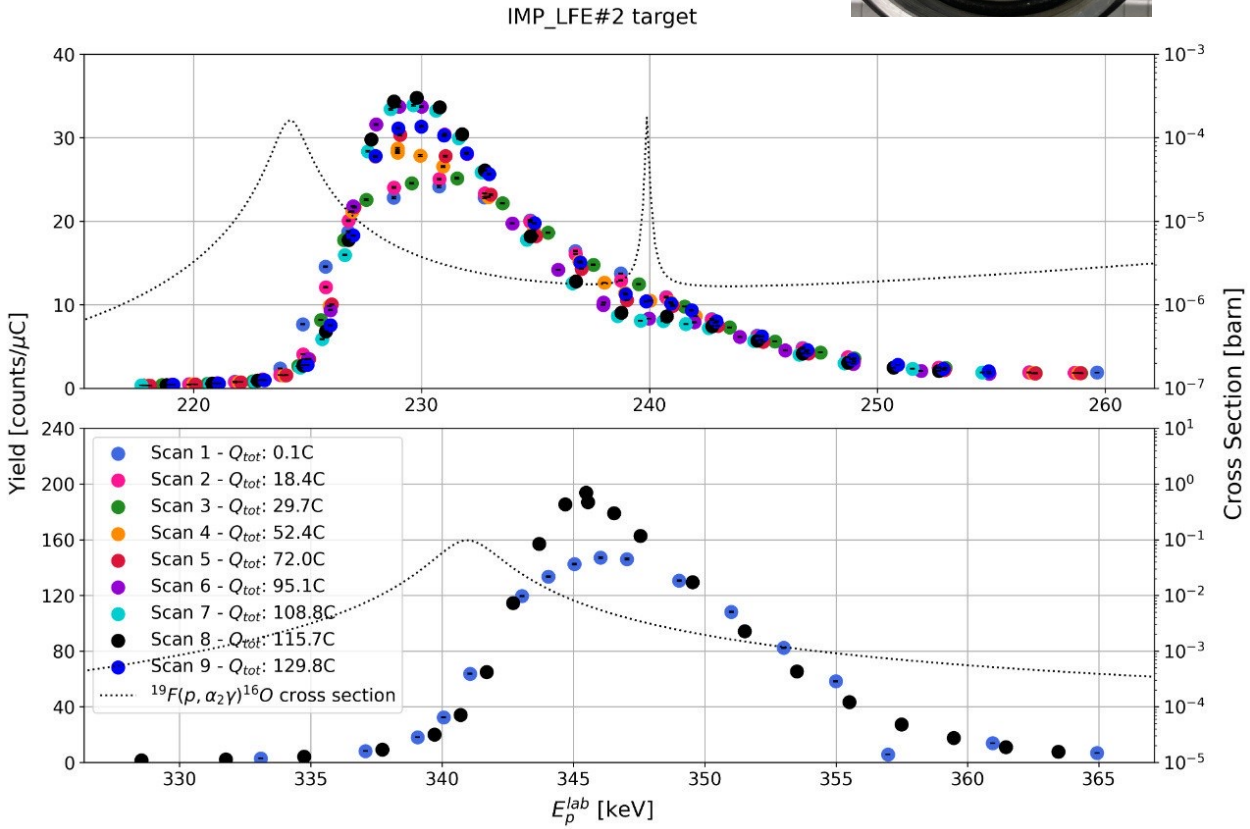
- Very stable up to **130 C** (degradation of **20%**)
- 3 times **higher yield** w.r.t. Ta



Implanted ^{19}F Targets

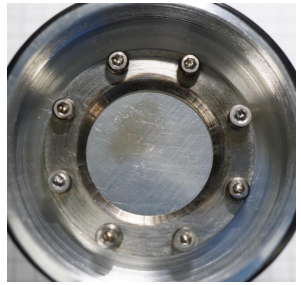
Implanted ^{19}F in Fe

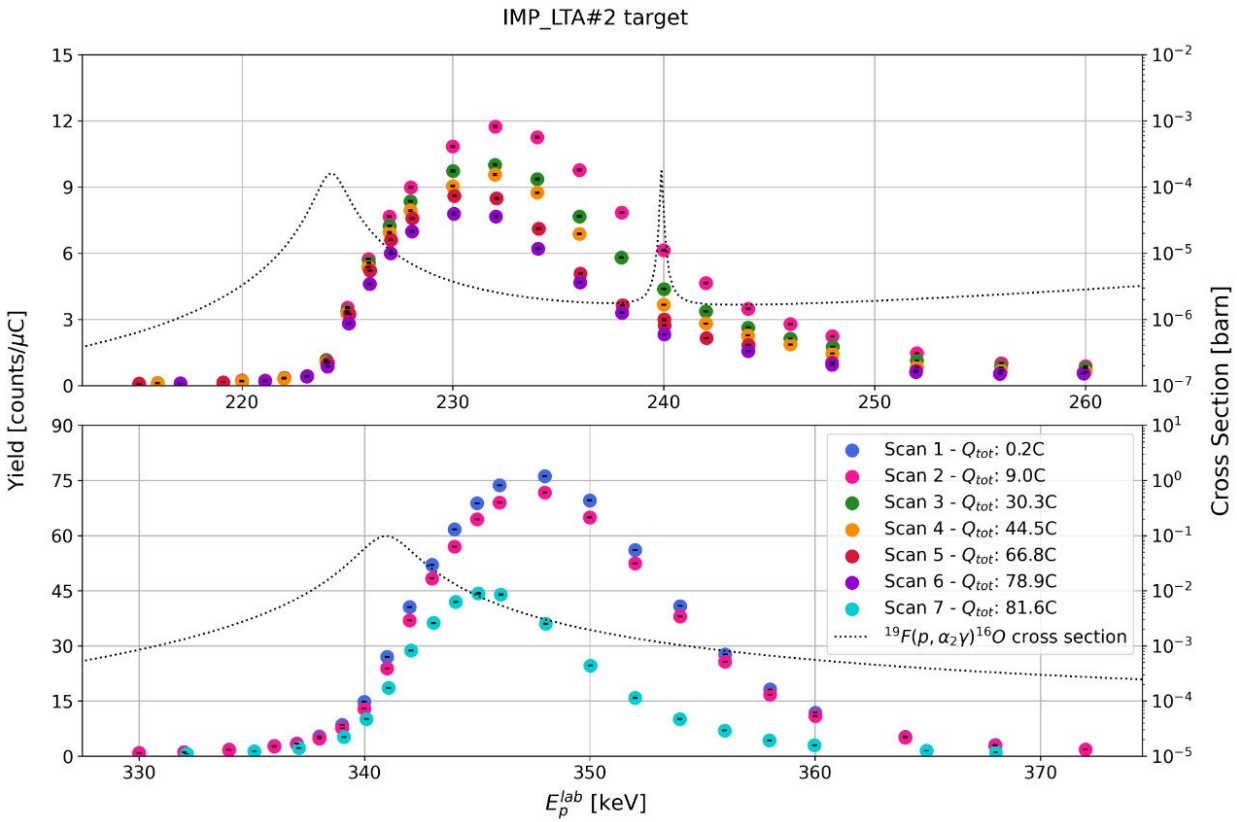
- Very stable up to **130 Colomb @ 300 µA** (degradation of **20%**)



Implanted ^{19}F in Ta

- Stable up to **81 C** (degradation of **50%**)
- **Lower yield** (3 times) w.r.t. Fe

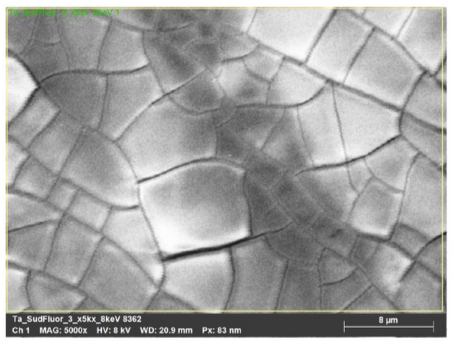




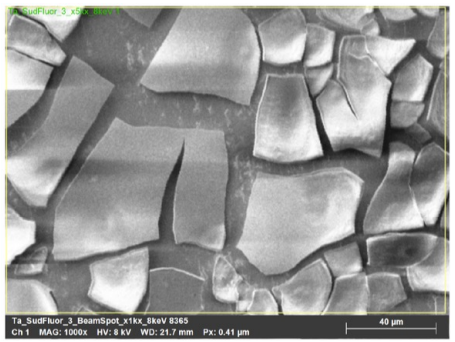
Fluorinated ^{19}F Targets

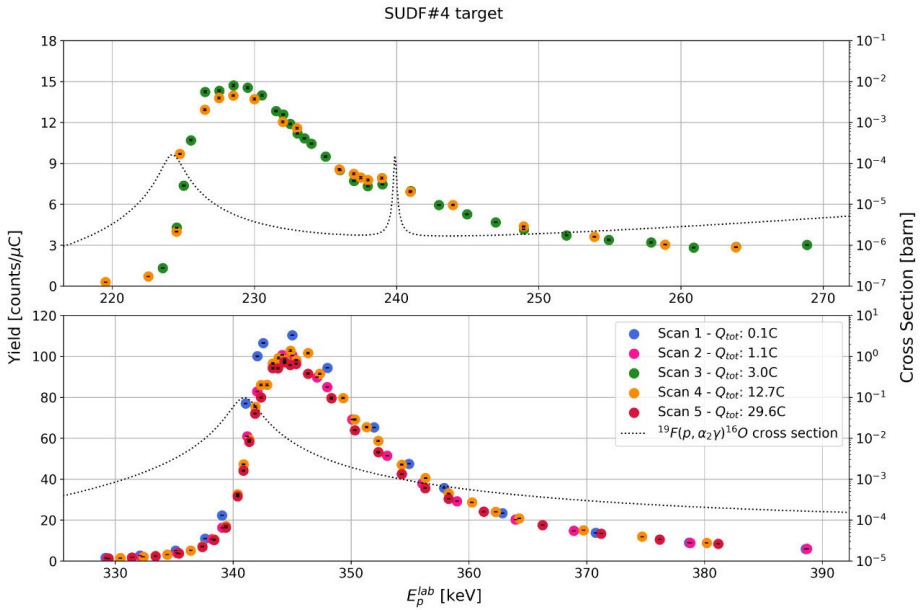
- New type of target produced by **SUDFLUOR** (France) company
- Produced by exposing **Ta backing** (at different temperatures) to **^{19}F** atmosphere
- Creates (almost) stable **TaF_5** layer
- Currently under analysis through **RBS**, **SEM** and **SIMS**

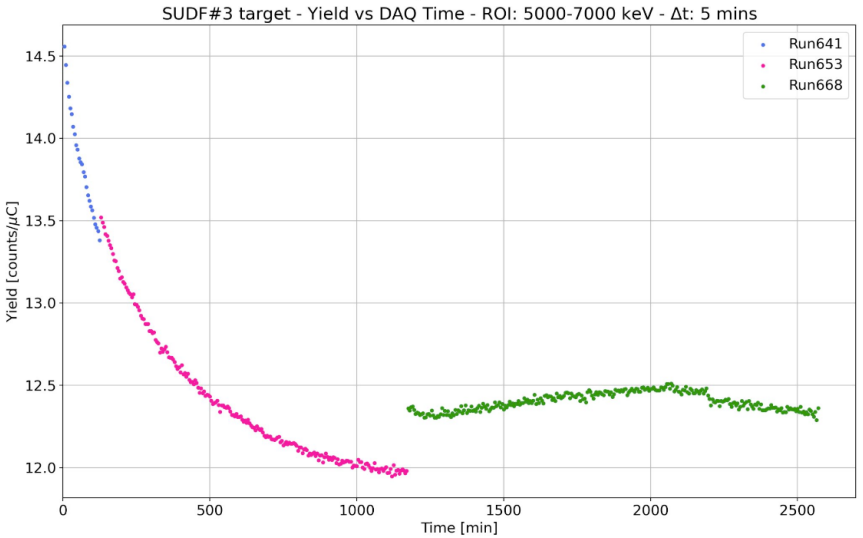
Fresh

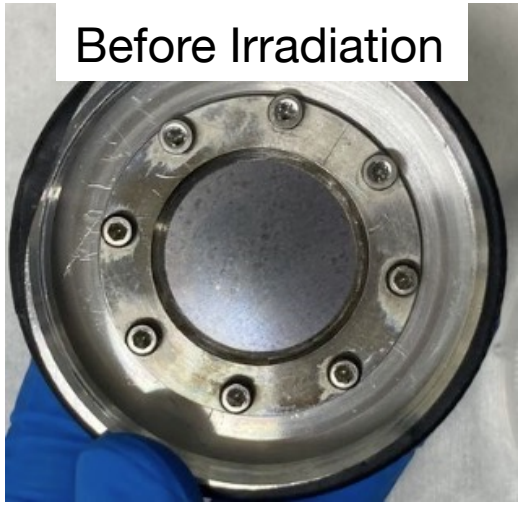


Irradiated









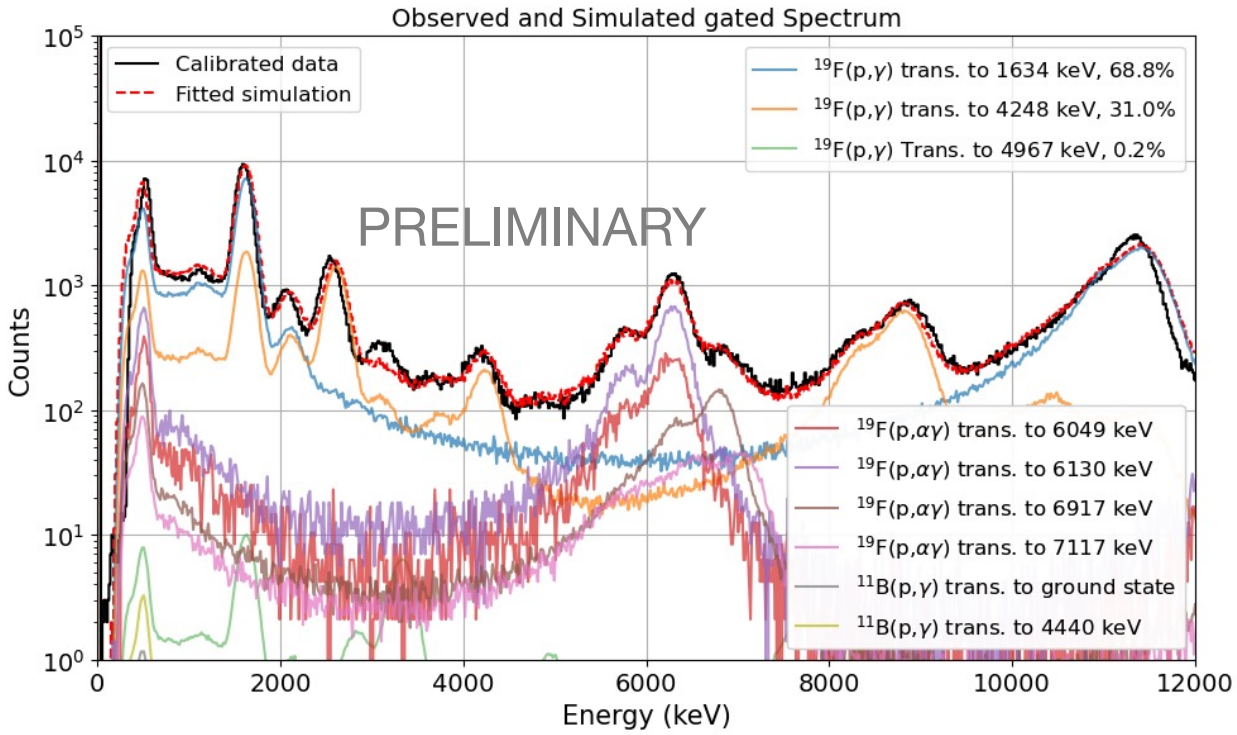
$^{19}F(p,\gamma)^{20}Ne$ – 225 keV Resonance

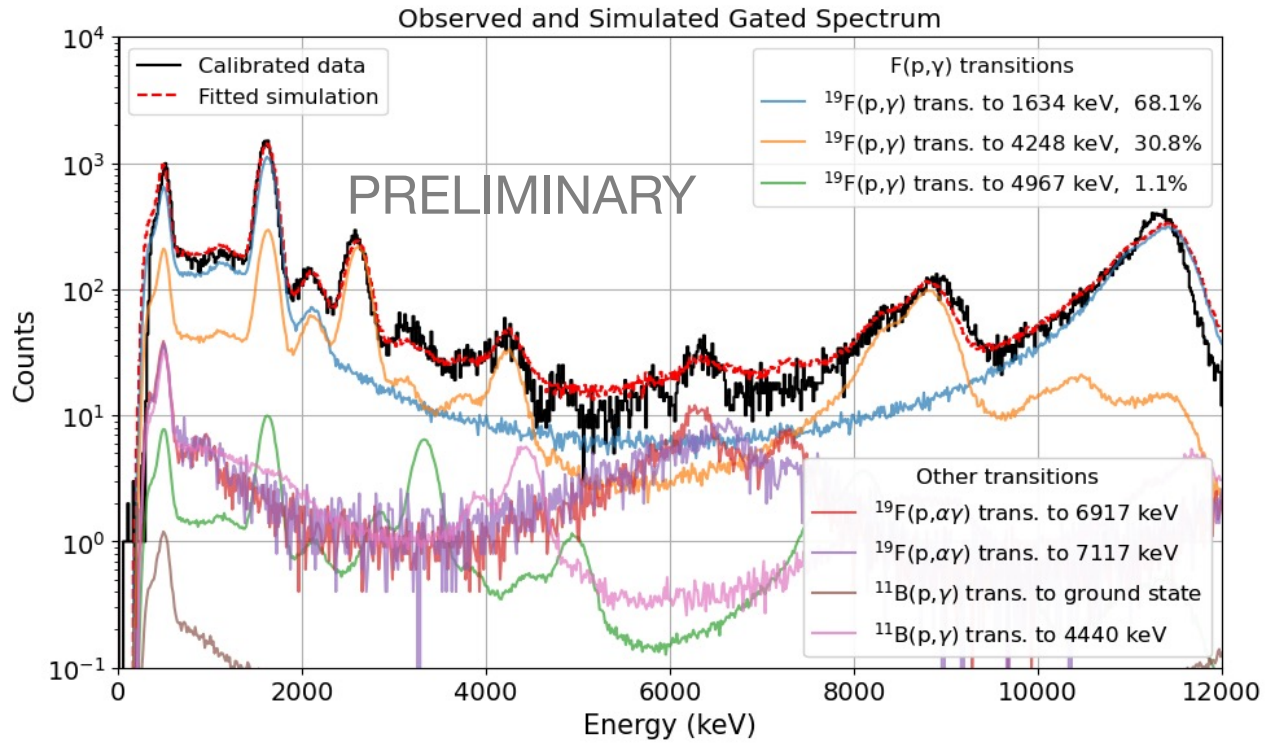
- Preliminary analysis of the **branching ratios** @ 225 keV resonance *close* to previous result
- Uncertainty analysis and other resonances **in progress**

Table 1 γ-transition branching ratios obtained for the resonances at $E_{c.m.} = 225.2$ and 323.9 keV

$E_r^{c.m.}$ (keV)	G.S	1.634 MeV	4.248 MeV	4.967 MeV
225.2	–	62%	35%	3%
323.9	34%	45%	–	21%

Chen et al, Nucl. Sci. Tech. **35**, 143 (2024)





Conclusions

- Preliminary results @ LUNA shows great stability of the implanted targets
- **New type of ^{19}F target** has been developed with the **thinnest profile up-to-date**
- A lot of data to be analyzed but **preliminary results show promising results**
- **Future goal:** reduce the ^{11}B content in Ta backing

Conclusions

- Preliminary results @ LUNA shows great stability of the implanted targets
- **New type of ^{19}F target** has been developed with the **thinnest profile up-to-date**
- A lot of data to be analyzed but **preliminary results show promising results**
- **Future goal:** reduce the ^{11}B content in Ta backing

Thank you for attention!

LUNA Collaboration

R. Perrino | INFN Lecce
A. Formicola | INFN Roma
M. Campostrini, V. Rigato | INFN LNL
O. Straniero | Osservatorio Astronomico di Collurania
F. Cavanna, P. Colombetti | Università di Torino and INFN Torino
B. Dipali, T. Chillery, F. Ferraro, R. Gesué, M. Junker | INFN LNGS
M. Lugaro | Konkoly Observatory, Hungarian Academy of Sciences
D. Bemmerer, E. Masha, A. Boeltzig | Helmholtz-Zentrum Dresden-Rossendorf
R. Depalo, A. Guglielmetti, G. Gosta | Università degli Studi di Milano and INFN Milano
S. Zavatarelli | Università degli Studi di Genova and INFN Genova
G. F. Ciani | INFN Bari
M. Aliotta, L. Barbieri, C.G. Bruno, A. Compagnucci, R. Bonnell, J. Marsh, D. Robb | University of Edinburgh
Z. Elekes, Zs. Fülöp, Gy. Gyürky, L. Csedreki, T. Szücs | Institute of Nuclear Research, ATOMKI
R. Biasissi, C. Broggini, A. Caciolli, R. Menegazzo, D. Piatti, J. Skowronski | Università degli Studi di Padova and INFN Padova
A. Best, D. Dell'Aquila, A. Di Leva, G. Imbriani, D. Mercogliano, D. Rapagnani | Università degli Studi di Napoli and INFN Napoli

Thank you!